COAL GAS, WATER GAS, ELECTRICITY

AND THE

DEFECTS OF EXISTING APPARATUS,

TOGETHER WITH

A Description of H. C. Rew's Improved Apparatus

FOR THE MANUFACTURE OF

HIGH CANDLE POWER

ILLUMINATING AND HEATING GAS.

THE FUEL OF THE FUTURE.

CHICAGO:
RAND, McNALLY & Co., PRINTERS AND ENGRAVERS.
1887.

TO THE LEADERS

In every department of literature, science, art, improvement, progress and reform, this book is dutifully and most respectfully inscribed by

THE AUTHOR.

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3.25.87

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INDEX.

THE NECESSITY FOR IMPROVED GAS APPARATUS.

The necessity for improved apparatus for the manufacture of gas can be best appreciated by enumerating the defects of the various coal bench and water gas processes now in use.

DEFECTS OF THE COAL BENCH PROCESSES.

1st.—Coal benches and retorts are expensive to construct and maintain, laborious and slow to operate, and expose unnecessarily large surfaces to the radiation and loss of heat.

2d.—Owing to the interposition of the retorts, only an indirect contact of heat with the coal being coked is possible. As retorts are very poor conductors of heat, three and a half to four hours are required to carbonize the coal, thus adding to the cost of the labor, and of the gas generated, and restricting the production.

NOTE.—By the direct contact of heat, bituminous coal can be carbonized in less than half an hour.

3d.—A large portion of the condensable vapors arising from the retorts, instead of being heated and expanded into a fixed gas, are, on the contrary, chilled and condensed into tar, by being plunged into and through the water in the hydraulic main.

4th.—A large loss of heat and gas is caused by opening the retorts, withdrawing the incandescent coke, and quenching it with water.

5th.—The retort and coal bench system is best adapted for the manufacture of coke and tar. For such purposes, no better apparatus could be devised. These are, in fact, the principal products of the works, and gas is really the "by-product." The coke and tar, being nearly pure carbon, are much more valuable for the manufacture of gas than for any other purpose; but they can not be further utilized in the retorts. Their salable value does not exceed 30 to 35 per cent. of the salable value of the gas, though capable, when properly used, of producing much more gas than the volume of volatile hydrocarbons first driven from the coal.

6th.—Another apparently insurmountable defect in the retort process is,—the low candle power of the gas generated. To compete with the electric light (which has evidently come to stay), a gas of high candle power is required. Coal gas lacks one of the principal and most essential elements of a high candle power gas utilizable in large burners; viz., carbonic oxide (C O).

Coal gas contains only 5 to 10 per cent. of this gas, and therefore, when it is burned, in case it is enriched with heavy hydrocarbons, the combustion is imperfect, smoke is produced, and a portion of the carbon is thereby lost and wasted. Illuminating water gas contains 25 to 35 per cent. of carbonic oxide, owing to the presence of which, when burned, a clear white, practically smokeless flame is produced, which may be of very high candle power.

DEFECTS OF THE WATER GAS PROCESSES.

The defects in all of the cupola systems of water gas manufacture, can be stated as follows, viz.:

1st.—A large amount of heat is blown out of the tops of the apparatus and lost, while heating up the combustion and fixing chambers, as the natural and strong tendency of the hot gases to rise, and escape from the openings in the tops of the generators and superheaters, is accelerated by the air blasts.

2d.—A large amount of heat is driven out of the apparatus into the water seals, and lost when making gas, by the operation of the current of steam and hot gases passing through the apparatus in an upward direction, and the loss of heat is equivalent to the loss and waste of coal.

3d.—In the case of most of the cupola water gas systems, the ash pits in the generators are chilled by the cold air blasts; then, when steam is admitted below the grate bars, it is condensed, and rapidly puts out the fires at the bottom, clogging the base of the combustion chambers with dead coal, and the steam is apt soon to pass through the fires without being wholly decomposed (*i. e.*, broken up by contact with the incandescent carbon, forming carbonic oxide and hydrogen gas); and, as the passage of steam through the fuel rapidly chills down the fires, no useful purpose is accomplished, and loss and waste are caused thereby.

4th.—In the case of other well-known water gas systems, an additional large loss of heat results from sending the non-illuminating water gas from the generator to a separate and special holder, where the heat contained in it is entirely lost. Special retorts are also required, and heated up in the usual manner, to re-heat, carburet and fix the enriched water gas, which adds largely to the cost of the construction and maintenance of the apparatus, and thus to the cost of the gas.

5th.—All of the water gas apparatus now in use are confined to the use of hard coal (or coke) and naphtha. The demand for naphtha has now increased to such an extent that prices have been advanced, and are now apparently based upon the principle of "all that the traffic will bear;" and, of course, the traffic will now bear a price which brings the cost of enriched water gas up to the cost of coal gas. As the manufacture and sale of naphtha is in the hands of, and controlled by, a comparatively few individuals, it is not likely to sell again at low prices. To such an extent have prices been advanced that gas companies that once found the manufacture of water gas from hard coal and naphtha profitable and economical, have now started up their coal benches again. In some cases the use of hard coal and naphtha apparatus has been entirely discontinued. In others, coal gas and water gas plants are used together, as described on the following page.

BITUMINOUS COAL.

Numerous experiments tried in the various water gas processes, have demonstrated that it is impracticable to raise bituminous coal to the necessary incandescence for decomposing steam, unless the steam is mixed with air to support combustion, as is done in the Siemens and other "producers," used for supplying a partially combustible heating gas, which is burned while hot as it comes from the producers, in regenerative furnaces used for manufacturing iron, glass and steel, and for other fuel purposes. This method is not admissible in the manufacture of an entirely combustible heating and illuminating gas, for the reason that the gas resulting

is charged with 65 to 70 per cent of incombustible nitrogen (derived from the air), which deteriorates its heating and illuminating qualities.

In the manufacture of water gas from bituminous coal, it has therefore been found necessary to first coke or carbonize the coal in retorts by the indirect contact of heat (thus making it equivalent to hard coal), then to open and withdraw the coke from the retorts, and transfer it to the water gas furnaces in a chilled or entirely cold condition, where it could be raised again to incandescence by an air blast for the purpose of decomposing steam by passing the steam through the incandescent coke.

In confirmation of the foregoing, the following is clipped from the May, 1886, number of the *Progressive Age and Water Gas Journal*, page 71, being a portion of an article entitled "PROFESSOR LOWE'S VALUABLE SUGGESTIONS," in reference to the Philadelphia Gas Works:

> "In cities like Philadelphia, and other large cities where bituminous coal is cheaply obtainable, gas works would not be complete until it had both coal and water gas methods erected in the best manner. Appreciating this, the company which I represent, some time since secured control of one of the most complete systems of regenerative gas furnaces for the production of coal gas, which can be operated either independently or in conjunction with a water gas plant; and, when worked in conjunction with water gas generators for such a city as Philadelphia, I would only make what water gas could be produced by the use of the surplus coke drawn from the retorts. In this way the company would not be compelled to hunt a market for coke, and then often at a price which hardly pays the handling. The second advantage of making part water gas is that the candle power can be raised to twenty-two or twenty-four candles without smoking, which can not be done if made from coal or oil without the mixture of water gas. There is still another great advantage in having both kinds of plants; namely, it can more readily control the market for gas-making materials: if oil (naphtha), the enricher of water gas, reaches too high a price, its use can be discontinued; and, on the other hand, if coal reaches too high a figure, or the supply becomes short on account of strikes or other causes, a larger proportion of water gas can be manufactured. For these reasons I would recommend this plan in nearly all large cities. It is hard to overestimate the advantage of using up all surplus coke in this way."

The soundness of the "valuable suggestions" of the wise and good Professor is evidently heartily endorsed by the editors and proprietors of the *Progressive Age*, as the article from which the above is taken sagely concludes as follows, viz.:

> "We know Prof. Lowe's opinion, as set forth in this brief article, will have much weight with thinking citizens who desire the best possible disposition of the gas works difficulty."

Although the foregoing is the usual course of operations, "thinking citizens" will, nevertheless, observe that the method advised by the learned and honored Professor, requires the construction and operation of two distinct sets of apparatus; viz., coal benches, or retorts for utilizing bituminous coal; and water gas furnaces for utilizing hard coal (or coke) and naphtha,—of which apparatus the company represented by the Professor have, as he states, "secured control," but which are, nevertheless, subject to all of the defects previously mentioned.

Such apparatus have been in use long enough to fully demonstrate the fact, that, by the use of such crude, primitive and imperfect methods of manufacture, gas never has been, and never can be, produced in sufficiently large volumes and at such low cost as to cause its adoption as a common article of fuel. The delivery of gas throughout the year (principally for illuminating purposes) now averages only about four hours per day. Twenty hours per day the costly network of mains and pipes lie idle in the ground. Five-sixths of the interest paid upon the cost of the works is lost and wasted by their enforced idleness a large portion of the time, caused by the small volume and high cost of the gas generated, and the consequent limited uses to which it can be applied. As long as the Professor recommends a continuation of this policy, it is questionable whether he and the company he represents have fully comprehended and grasped every detail of "the gas works difficulty."

UNDEVELOPED WATER GAS TERRITORY.

The range of improvement, therefore, lies in the direction of providing in one compact apparatus, and in one continuous process, for rapidly generating gas in large volumes by carbonizing bituminous coal by the direct contact of heat, without the interposition of practically non-conducting retorts; for raising an ample quantity of the resulting hot coke to incandescence by air blasts for decomposing steam without opening or withdrawing the hot coke from the apparatus; for generating water gas by passing superheated steam through the incandescent coke without extinguishing the fires at the bottom; for carbureting the resulting water gas with the volatile hydrocarbons thrown off from the bituminous coal while being carbonized, and enriching the gas still further with the rich gases generated by vaporizing and volatilizing crude petroleum by the direct contact of heat; for combining and fixing the mixed gases by heat into a homogeneous gas; and for better methods of storing and retaining the heat in the coking, combustion, superheating and fixing chambers.

When the foregoing is successfully accomplished, the wide gap now existing between gas works as they are and gas works as they should be will have been filled up. Gas of high candle power can then be manufactured in such enormous volumes, and at such low cost, as to enable gas companies to furnish it as a common article of fuel.

The handling of crude fuel and ashes will then all be done at the gas works by machinery. Gas fires of every description, instead of being, as at present, the ornamental plaything and luxury of the rich, will become the common necessity of rich and poor alike in every home and factory. The iron interests will be stimulated to greater activity to supply the iron required to increase the capacity of gas works everywhere. The prosperity of the iron and gas industries will carry prosperity to every commercial interest in the country. With new, increased and more diversified industries, harmony will be promoted between labor and capital, invention will be stimulated and encouraged, and the world will have taken another stride away from more of the barbarisms and crude methods of the past, toward the higher and better civilization of the future.

HIGH CANDLE POWER WATER GAS, AS MANUFACTURED FROM BITUMINOUS COAL AND CRUDE PETROLEUM BY HENRY C. REW'S IMPROVED PROCESSES AND APPARATUS.

All of the foregoing requirements are fully provided for in the improved apparatus shown in the accompanying drawings, in which Figure 1 represents a perspective view of one form of the apparatus, which is preferably constructed of fire brick, encased in gas-tight iron shells, with a layer of any suitable non-conducting material between the brick work and the outer shells.

This form of apparatus is designed to furnish gas for fuel, power and illuminating, to small towns and villages, where only a moderate volume of gas is required. The capacity of this apparatus can, however, be greatly increased by widening out the various chambers. No greater height is required. In this manner this apparatus can be adapted to large works.

Figure 2 is a plan view of the same apparatus, showing the relative position of the fuel and regenerative chambers, the water seal, and outlets for gas and waste products of combustion, inlets for steam, air, oil, etc.

Figure 3 is a section through the line 1 1 of Figure 2, and is an elevation of one coking and combustion chamber, and a vertical section of the corresponding chamber. Both of these structures are alike in external and internal construction, and have the same inlets and outlets.

Figure 4 is a horizontal section through the line 1 1 of Figure 3, showing the internal horizontal construction of one coking chamber and the openings through which the coke passes from the coking to the combustion chamber.

Figure 5 shows the details of the ash outlets at the base of the combustion chambers.

Figure 6 is a vertical section of one coking and combustion chamber and of the connected regenerative chamber on the line 2 2 of the plan view. The corresponding chambers shown in the plan view are the same in external and internal construction, and have the same inlets and outlets. The solid arrows in all of the drawings indicate the direction in which the air blasts, coal gas and products of combustion pass while heating up the apparatus previous to making gas. The broken arrows indicate the direction in which the steam, water gas, coal gas and oil vapors pass when making gas.

Figure 7 shows an elevation of one regenerative chamber, with its connecting air blast pipe and outlets for gas and products of combustion, water seal, etc., on line 3 3 of the plan view. The corresponding regenerative chamber, shown in the perspective and plan views, is similar in construction, and has the same inlets and outlets.

Figure 8 is a perspective view of a different form and modified construction of the same apparatus, adapted for use in large cities, where an enormous volume of gas is required to supply the large demand for fuel, power and illuminating.

Figure 9 is a horizontal section of this apparatus through the combustion and regenerative chambers, and shows the central air-blast inlet for the combustion chambers, the air-blast inlets for the regenerative chambers, the flues connecting the combustion and regenerative chambers, the outlets for gas and products of combustion, water seals, etc. The apparatus may be constructed one-half of the size shown in the drawings, with but single outlets for gas at each end. The width of the apparatus on the line of the grate bars is limited only by the length of the tools that can be conveniently handled in cleaning the grates, removing ashes, cinders, etc. The thickness of the fuel bed on the line of the air blasts should not exceed three feet, as experience shows that air blasts can not penetrate and cause complete combustion of fuel beyond that limit.

Figure 10 is a vertical section of this apparatus on either of the lines X—X, of Figure 9, showing the relative position of the coking, combustion and regenerative chambers, the air-blast pipes and the flues connecting the chambers, also the outlets for gas and products of combustion, water seals, etc. The attention of the reader is called to the points of similarity between this apparatus for manufacturing gas and the Siemens regenerative furnace,* for burning gas. It will be seen that the waste products of combustion are sent from the bottom instead of the top of the regenerative chambers in both instances, by which means the heat generated by the combustion of the gas and coal is retained in both apparatus in the most economical manner, and aids in maintaining the heat of the central chambers.

* Note.—Vertical sections of the Siemens Gas Producer, with the analysis of the gas generated; also vertical sections of the Siemens regenerative furnaces, can be seen in the Encyclopedia Britannica, volume 13, pages 294, 295 and 341. The reader will there find the method explained, by which (with a gas only 30 to 35 per cent. combustible, and which generates a heat of only 700 to 800 degrees when first burned) a steel-melting temperature of 3,500 to 4,000 degrees is raised and maintained in the central melting chambers.

Figure 11 is a vertical section of the wall between the combustion chambers, showing the air ports and connecting flues and the construction of the special fire brick required to form the perforated wall dividing the combustion chambers. The principles and method of operating are the same in both forms of the apparatus.

Similar letters of reference designate like parts in all of the drawings, as well as in the drawings accompanying the Patent granted to the author, April 6, 1886, for improvements in the Manufacture of Gas, No. 339,471.

The centrally located chambers A A^1 are generating or combustion chambers, preferably connected below the grate bars or at the base by the flue C. Flues for air blasts (D D^1), and pipes for steam (G^4 G^5) and *gas (H^2 H^3), enter both of the ash pits below the grate bars. Suitable doors (B B^1) are provided for cleaning the grates, removing ashes and other purposes.

Flues L L^1 connect the upper part of chambers A A^1 (say four to six feet above the grate bars) with the upper part of chambers E E^1. The chambers E E^1 are regenerative or heat-storing chambers, and are nearly filled with loosely piled refractory material. The combustion and generating chambers, A A^1, are surmounted by the coking and carbonizing chambers, A^2 A^3, and are directly connected therewith by open flues, a^2 a^3, in order that hot gases may circulate between the chambers, and that the coal, when carbonized, may pass down freely by gravity from the coking chambers into the combustion chambers. The coking chambers are preferably fitted at the top with any suitable tight feeding apparatus or gas-tight covers, and openings (Z Z^1) with covers may be provided for clinker bars, used to facilitate the downward movement of the coke from the upper to the lower chambers. A pipe, A^4, controlled by valve a^4, connects the coking chambers at the top, and pipes A^5 A^6, controlled by valves a^5 a^6, may connect the upper part of the coking chambers with the upper part of the regenerative chambers.

The regenerative chambers, E E^1, are similarly supplied at their tops with hot air inlet pipes, F F^1, steam inlet pipes, G G^1, and oil inlet pipes, M M^1, all of which pipes are controlled by suitable valves, as indicated. At their bases they are similarly supplied with *gas inlet pipes, H H^1, *air inlet pipes, F^2 F^3, and steam inlet pipes, G^2 G^3, also with similar outlet pipes for products of combustion, K K^1, and gas outlet pipes, O O^1, all of which inlet and outlet pipes are also controlled by suitable valves, as indicated.

The operation of the apparatus is preferably as follows: The chambers A A^1, A^2 A^3, are first filled with hard coal or coke, and the openings at the tops of the chambers are tightly closed.

The valves k k^1, controlling the outlets (K K^1) for products of combustion, are then opened. The fuel is ignited on the line of the grate bars, and air blasts are admitted below the grate bars through pipes D D^1, which urges combustion. The products of combustion (carbonic oxide, about 20 per cent., combustible; carbonic acid, about 8 per cent., and nitrogen, 72 per cent., non-combustible) pass through flues L L^1, into the tops of the regenerative chambers, E E^1. Air, preferably heated by passing upward through flues in the walls of the regenerative chambers, is then admitted through pipes F F^1, which burns the carbonic oxide, and the highly heated incombustible products of this second combustion (carbonic acid and nitrogen) pass down through the refractory material and out at the outlets K K^1, leaving their heat in the brick work. When the fuel in the combustion chambers has been raised to incandescence and the brick work sufficiently heated (as observed through properly provided peep holes),

* NOTE.—The gas and air inlet pipes are not shown in the drawings, as they are but seldom required, and can be readily attached at any time.

the air blasts are shut off. Jets of steam are then admitted through pipes G G^1 into the tops of the regenerative chambers, in order to drive out the incombustible gases remaining in the brick work. The outlets (K K^1) for products of combustion are then closed, and, say, the valve o^1, to the outlet for gas, O^1, is then opened. Steam, air or gas, or any desired mixture of the same, is then admitted at the bottom of chamber E through pipes G^2 F^2 H, and is driven up through the heated brick work, raising the steam or mixed gases to the temperature (say 2,000 degrees) necessary for their thorough decomposition when brought into contact with incandescent carbon. From the top of chamber E the mixed gases are driven through the flue L into and down through the incandescent fuel in chamber A, then through the flue C up and through the incandescent fuel in chamber A^1. By their passage through the chamber E, where they are first highly superheated, then through and into contact with the incandescent fuel in chambers A A^1, the gases are completely decomposed, and pure carbonic oxide and hydrogen, highly combustible gases (provided that gas or steam only, or a mixture of them, are admitted to the superheating chamber E), enriched by the hydrocarbons derived from the coal, are the result. From the top of the combustion chamber A^1, the hot gases are passed through the flue L^1 into the top of the regenerative or heat-storing chamber E^1, then down through the heated brick work, where they are combined and fixed into a homogeneous gas, and out at the outlet to the gas main O^1. A test burner is attached to the main, and, in case the gas needs still further enriching, liquid hydrocarbons or their vapors may be introduced into chamber E^1 through the pipe M^1 and other controlling pipes; and, in their passage down through the heated brick work, they are combined and fixed with the other gases into a homogeneous gas of any desired candle power, according to the quantity of oil and rich gases admitted through pipe M^1. While making gas, the oil pipes may discharge oil directly into the coking chambers, wherein it is volatilized and vaporized by the direct contact of the heat, and the vapors may pass from thence, through the connecting flues, into the enriching and fixing chamber. Air alone, or a mixture of steam and air, may be used as a gaseous medium in the manufacture of gas, provided that it is desired to generate a heating gas which contains a portion of incombustible nitrogen. A non-illuminating natural gas may be used as a gaseous medium in the manufacture of gas instead of steam, and converted into an illuminating gas of high candle power. This method is advantageous in regions where natural gas can be cheaply and abundantly obtained. As it is principally hydrogen, and contains little or no oxygen, the heat of the fires is longer maintained, and it has been found necessary to highly heat hydrogen in order to cause it to absorb and combine with the carbon, and to hold it in solution until carried to the place of combustion.

As the inlets and outlets to the regenerative chambers E E^1 are similar, the operation of gas-making can be reversed at will, according to the condition of the fuel and regenerative chambers.

For instance, after heating up the apparatus, steam, air or gas, or any desired mixture of them, may be passed into the base of chamber E^1, and through the combustion chambers, and the resulting gases may be combined and fixed in chamber E, and the gases passed out of the apparatus through the outlet O. The gas outlets, O O^1, may discharge the gas into a common water seal, or hydraulic main, and the waste products of combustion may also be discharged into a single chimney or smoke-stack, as shown in Figs. 1, 2 and 3.

The combustion chambers, A A^1, are supplied with additional hot fuel as fast as it is consumed, by the coal or coke in the upper chambers, A^2 A^3, falling by gravity, or being crowded down by the clinker bars, through the open connecting flues a^2 a^3. As the coke or hard coal first supplied sinks down in the upper chambers, A^2 A^3, fresh bituminous coal is supplied through the openings at the tops of the chambers, after each run of gas, or as required. As the coal enters the carbonizing

chambers, it is brought into direct and continuous contact with the heat in the combustion chambers and regenerators, and the volatile hydrocarbons are thrown off during its descent through the upper chambers. While heating up the apparatus, in the manner described, the rich gases evolved in the coking chambers may pass down through the coal, or through the outside pipes A^5 A^6, into the combustion chambers, or regenerators, where they will mingle with the products of combustion passing through flues L L^1, and with the air entering the upper parts of the regenerators through ports connected with the vertical flues F F^1, and be burned, and thus aid in quickly heating the regenerative chambers previous to making gas.

While making gas, in case the chamber E is used as a superheating chamber, and the chamber E^1 as a combining and fixing chamber, the coal gas valve a^5 is closed, and the valves a^4 and a^6 are wholly or partially opened, thus directing the rich coal and oil gases from both coking chambers into the top of the combustion chamber A^1, or into the top of the combining and fixing chamber E^1, where they are mixed with the water gas generated in the lower combustion chambers, and aid in enriching and carbureting the gases; or, when operating the apparatus in a reverse direction, the rich coal and oil gases generated in the coking chambers may, in like manner, be directed into chamber E. By this method of manufacturing a carbureted water gas and treating bituminous coal, less oil will be required to enrich the gas to the desired candle power, and the coke and tar, which are the principal products (or so-called "residuals") of coal gas works, may thus be completely utilized, and wholly applied to the manufacture of gas.

It will be seen that the apparatus may be divided and made into two separate and complete sets of generators and fixing chambers by closing the flue C, say by placing a valve or diaphragm on the dotted line x x, or by closing the flues with masonry, or in any suitable manner. Then, after heating up the apparatus as described, air, steam or gas, or any mixture of them, may be driven into the ash pits below the grate bars through pipes D D^1, G G^1, H^2 H^3, and passed up through the combustion chambers, A A^1, and the resulting gases through flues L L^1, into the side regenerative chambers, E E^1, where they may be enriched with the volatile hydrocarbons generated in the coking chambers, and with oil vapors, as described, and combined and fixed by passing them down through the heated brick work in chambers E E^1. This method of operating the apparatus is convenient when it is desired to restrict the manufacture of gas by using only one side of the apparatus, or to shut down a part of the apparatus for repairs; although less satisfactory results are obtained, for the reason that the steam partially puts out the fire when driven in at the base of the combustion chambers, and the decomposition of the gaseous mediums used in making gas is less perfect and complete when they are not first superheated, and when they are passed through only a single bed of incandescent fuel to be decomposed.

It will be understood that I do not limit myself to the precise arrangements and details of my improved apparatus as hereinbefore described with reference to the accompanying drawings, as the construction may be variously modified without departing from the nature of my invention. As, for instance, the hot products of combustion and gases may be passed into the base of regenerative chambers and out at their tops or sides, the regenerators may be placed directly underneath the combustion chambers, the apparatus may be constructed all in one or two structures with suitable dividing gas-tight walls, and the construction of the combined combustion and coking chambers may be modified in various ways.

The advantages gained by this improved construction and operation of my apparatus are as follows:

ADVANTAGES GAINED.

1st.—By passing the hot products of combustion *downward* through the brick work instead of *upward*, the heat is stored and retained in the regenerative chambers in the best manner, and according to the well-established principles shown in the operation of regenerative furnaces used for burning producer gas and generating heats for melting and combining metals, etc., in the manufacture of iron, glass, steel, etc. In these generators, the heat stored in the regenerative chambers aids in maintaining the heat of the combustion chambers, in the same manner that the heat stored in the regenerative chambers of metallurgical furnaces aids in maintaining the heat in the melting chambers. This special and very valuable feature is shown in no other apparatus for generating water gas.

2d.—The heat in the combustion and regenerative chambers is brought into direct and continuous contact with the bituminous coal in the coking and carbonizing chambers, without the interposition of valves or non-conducting retorts.

3d.—The combustion chambers are continuously supplied with highly heated fuel, without being opened, and are not chilled by the introduction of fuel in a cold condition as in other apparatus, from which a large volume of gas and heat escapes and is lost, when the generating chambers are opened to be charged with fresh and cold material.

4th.—The apparatus may be operated in whole or in part, and thus not require to be wholly shut down for repairs or other purposes at any one time. By this means, a practically continuous supply of gas is provided.

5th.—Bituminous coal is quickly reduced to coke by the direct contact of heat, the resulting hot coke is raised to incandescence by an air blast, the volatile hydrocarbons evolved from the coal are used to enrich the water gas generated in the incandescent coke, which is entirely absorbed by and combined with the oxygen of the air, when heating up the apparatus, and with the oxygen of the steam when making gas; and thus the bituminous coal is wholly utilized in the manufacture of gas, including the coke, tar and heavy hydrocarbons, in one operation and apparatus.

6th.—An apparatus is provided in which either anthracite or bituminous coal may be used in the manufacture of gas, according to convenience and the greatest economy, and in which large volumes of high candle power gas may be generated with the greatest rapidity, and with a comparatively small amount of labor.

7th.—By discharging the oils used for enriching the gases directly into the coking chambers, a method is provided by which crude petroleum may be utilized as an enriching agent instead of naphtha. The oil sinks into and with the coal until it reaches the heat where every grade of the oil is vaporized by the direct contact of the heat, and the coal gas and oil vapors are passed into the fixing chambers, and there mingled with and enrich the water gas generated in the combustion chambers. It is understood that the oil is allowed to flow into the apparatus, only while gas is being generated, and that the "residuum" of the crude petroleum is burned with the coke while heating up the apparatus by air blasts as described, preparatory to making gas.

As crude oil is much more abundant and cheaper than manufactured naphtha, and contains much more carbon per gallon, it will be seen that great economy results from thus using it for enriching the water gas. It will also be seen that a gas of the highest possible heating and illuminating power may be produced.

8th.—As the apparatus is designed to manufacture gas very rapidly, and as fast as it is drawn away from the works by consumers, less proportionate holder room is required as compared with works, the products of which are principally made up of coke and tar, and which can, therefore, manufacture gas but slowly during the day, which is largely drawn off by consumers at night.

9th.—In proportion to their generating capacity, and adaptation to convert either anthracite or bituminous coal completely into gas and ashes, these apparatus are the cheapest and quickest to construct, operate and keep in repair, and expose the least possible surface to the radiation and loss of heat.

GAS IN GENERAL.

The inventor has worked on improved methods of gas manufacture for several years, with the idea in his mind, that, in this age of the world, it was as barbarous and unscientific for the consumer to use crude fuel as it would be to grind his own corn between stones, or pound his own wheat in a mortar. To-day, corn and wheat are sent to the mill, and the consumer uses the finished product. In the same way the crude coal should be sent to the gas factory, and the consumer should use only gaseous fuel, and that strictly on the ground of economy, and for the reason that he secures a better and more convenient fuel for less money. The consumer of crude coal saves only about fifteen per cent. of the heat and force of the coal, and loses fully eighty-five per cent. in his method of combustion. The consumer of crude fuel in his stoves, grates and furnaces, is practically running his own gas factory (for fuel must be turned into gas, either before or during the process of combustion); and practical experience demonstrates that fuel can be only partially turned into combustible gas by admitting air, which is composed of gases, practically eighty per cent. non combustible (nitrogen). This primitive method of manufacturing gas for fuel purposes results in great waste from the non-combustion of a large part of the gases produced and of carbon set free, which pass up the chimney unconsumed, in the form of smoke. Carbonaceous material can only be completely utilized in the manufacture of combustible gases by treating it with steam (as shown in these processes), which is composed of gases that are entirely combustible (oxygen and hydrogen). To-day gas is a luxury, and is used by not more than one-tenth of the population. When properly and economically manufactured, and delivered in large volumes at prices that drive crude fuel to the gas factory, the consumer will use gas as freely in his stoves, grates, furnaces, burners and engines, as he now uses crude fuel, and at no greater cost to himself, but at a largely increased profit to the gas factory; for, while the consumer can save only about fifteen per cent. of the fuel by burning it in a crude condition, the gas factory should save at least ninety per cent. by converting it into gas before combustion, and the difference—seventy-five per cent.—(less cost of manufacture and delivery) would represent the profit to the gas works.

The cost of delivering gas will also be greatly lessened by increasing the quantity delivered, and using the gas mains to their full capacity, day and night.

The substitution of gaseous for solid fuel, and the suppression of the constantly growing destructive and intolerable "smoke nuisance" in all of the large towns and cities of the country, which will, undoubtedly, result therefrom, is the aim and the ultimate end of all improvements in gas manufacture.

The inventor believes that these most desirable results can be reached by the general adoption and use of these improved and perfected methods: and that, in short, these processes will not only supersede all other methods of manufacturing gas of high candle power, but that they can not possibly be surpassed and superseded, as the best method is shown of storing and retaining heat in the apparatus; of bringing the heat into direct and continuous contact with the best, most abundant and cheapest varieties of both solid and liquid gas-producing materials; of supplying an abundance of incandescent coal for decomposing superheated steam without quenching the fires at the base; and of generating, enriching, heating, expanding and fixing the gases in one operation, and in one compact and comparatively inexpensive apparatus.

THE FUEL OF THE FUTURE.

The general public have but a faint conception of the exceedingly important part that the introduction of gaseous fuel is to play in the development of the industries and civilization of the near future, nor of the gigantic struggle for manufacturing and commercial supremacy now impending between cities located in the regions of natural gas and all other manufacturing cities in the world, that must certainly follow the already accomplished introduction and utilization on an enormous scale of natural gases into the manufactures and arts of the former-mentioned cities. The delivery of gas as a common article of daily and hourly use is, therefore, no longer a mere fancy or sentiment, and the dream of an enthusiast, but a matter of positive and growing necessity in order to relieve the population from the unnecessary labor and drudgery of handling crude fuel and ashes, and to enable manufacturers throughout the country, and others dependent upon cheap fuel, to obtain gaseous fuel of the finest quality without stint or limit, so that they may successfully compete with factories and populations located in the favored regions of Pennsylvania and elsewhere.

Owing to defective and imperfect systems of manufacture, comparatively little progress has been made in this direction, except in inventions for burning gas in the most beautiful and economical manner in stoves, fire places, engines, furnaces, and improved burners for purposes of illuminating. These appliances are in common use, and now the world is waiting for cheap and abundant gas. It has been proposed to lay long lines of heavy mains, and pipe natural gas from the Pennsylvania wells to the large cities, using powerful exhausters and fans to urge it through the pipes; but the heavy cost of the construction and maintenance of the mains, and the consequent high cost of the gas and the uncertainty of the supply, makes capital very timid of the outcome of such doubtful enterprises. An attempt is now being made to supply the city of Buffalo with gaseous fuel in this manner. To what extent natural gas can be conveyed such long distances, and sold at prices that will cause it to supersede crude fuel, remains to be seen. At a price equivalent to ten cents per thousand cubic feet, as at Pittsburg, it is demonstrated that natural gas supersedes crude fuel, and drives it out of use; but at fifty cents per thousand, the price proposed to be charged at Buffalo, natural gas will undoubtedly prove to be a luxury, and out of reach of the mass of the population, to whom crude coal will continue to be a cheaper fuel. It has also been proposed to deliver a non-illuminating water gas which can be rapidly and cheaply manufactured in large volumes by simply passing superheated steam through incandescent coal, and works of this description have been put into operation at Troy, N. Y.; but this method, beyond small limits, is defective and impracticable, for the reason that water gas of itself is an exceedingly light and volatile gas, and contains but a comparatively small number of heat units per cubic foot. It would be as reasonable to undertake to operate turbine wheels and furnish water power with wind, as to

attempt to supply the fuel of a city with such a thin gas as hydrogen, which is the unit of gases and the lightest gas known to science. At a very moderate calculation at least one thousand times as much of such a gas would be required for fuel as is now used for illuminating purposes. The author is indebted to Professor Elias Colbert, the accomplished mathematician of the Chicago *Tribune*, for the following very interesting calculation, viz.:

"The mains required to deliver 1,000 times as much gas as is now supplied through a 20-inch main, are shown in the following table:

No. of Mains.	Inches Diameter.	No. of Mains.	Inches Diameter.
1,000	20	50	66
500	26½	25	87½
250	35	10	126
100	50		

"This table is computed on the hypothesis that the pressure on the gas is the same in each case; the quantity delivered being proportional to the fifth power of the square root of the diameter. But in practice one ean increase the effective pressure in proportion to the square root of the diameter, and the velocity increases as the square root of the pressure. Hence, if the mechanical conditions permitted, the pressure might be so much increased with the size of the pipe as to allow the largest to be reduced to nine feet in diameter. It is probable, however, that the condensation involved by this pressure would be too great for ordinary qualities of gas; but the diameter of the largest could be reduced to less than ten feet, and the others in smaller proportion."

The laying of such a great number of mains in the streets is, of course, out of the question, and it is seen that when the number is reduced their size rapidly increases until the casting, transportation and laying are also entirely impracticable. Furthermore, in case a non-illuminating gas was delivered for fuel purposes, additional lines of mains would be required to deliver gas for illuminating purposes, thus greatly increasing the difficulty.

Combustible gases have value for heating purposes only in proportion to the heat units contained therein. For instance, 1,000,000 feet of water gas which contained only 200 heat units per cubic foot, would have no more value for heating purposes than 400,000 feet of gas which contained 500 heat units per cubic foot; and the disadvantages would be decidedly with the former, as larger pipe would be required to conduct it to the consumer, it would have no illuminating power, and furnish only a sharp, short and quick flame, while less pipe would be required to conduct the latter; it would have high illuminating power, and furnish the long and easy rolling flame so greatly desired by engineers and furnace men who are familiar with the use of gaseous fuel. It therefore follows that the very best gas that can be made, viz., an enriched water gas,—composed, as it is, of nature's highest combustibles, oxygen, hydrogen and carbon,—is not only the best and cheapest for a gas company to manufacture and deliver, but is also the most satisfactory for users of fuel to purchase and consume. This, then, is the coming "fuel of the future." It is believed that it will be fully as economical to construct these improved gas generators close to the place of consumption, and supply gas for all purposes, as to construct natural gas wells, and lay from fifteen to thirty miles of heavy gas mains from the wells to the place of consumption, as is now done at Pittsburg and other places.

Natural gas is delivered at Pittsburg and other places without meters, the cost of gas to the consumer being based upon what has previously been paid for coal to do the same work. The same method can be adopted everywhere when the manufacture of gas has been brought to perfection. By dispensing with meters the business can be still further improved and simplified, and the cost of gas lessened to the consumer, thereby greatly popularizing the use of gas for all purposes and increasing the demand.

ELECTRICITY AS AN ILLUMINATING AGENT, AND ITS DEFECTS.

The defects of the various systems of electric lighting can be enumerated as follows :

1st.—To generate the energy and force necessary to produce electric lights requires, in the present state of the art, a plant which is very expensive, both to construct and maintain, consisting of boilers and the fuel to generate steam, high speed engines, swiftly running dynamos, and the firemen and engineers to care for the boilers and machinery.

2d.—As only a moderate number of lights can be generated by a single plant, and which must be distributed within a small area, it follows that the light is very costly. The strong tendency of the electricity to radiate from the conductors and become dissipated in space is a defect that has not yet been corrected, though conductors of many kinds have been tried. It is known that not over one-fifth of the energy stored in the coal is developed in the crude manner of converting it into gas and burning it under the boilers, and it is also estimated that not to exceed one-third of the force and energy generated in the dynamos is developed in the lights. Thus it is apparent that not over one-fifteenth of the value of the coal is saved, and that fully fourteen-fifteenths is lost and wasted by these methods of illumination.

3d.—The arc light, especially, is very injurious and destructive to the eyesight, as the severe "flickering" of the light (resulting from the variations in the speed of the machinery and the constantly changing shapes of the carbon points) causes the pupil of the eye to rapidly dilate and contract, beyond the point of safety and endurance.

Constant efforts have been and are now being made to overcome the foregoing defects. The newspapers have announced that Professor Edison has given himself to the task of solving, within five years, the problem of generating the electric incandescent light directly from the combustion of coal, without the intervention of the now used intermediary boilers, engines and dynamos, as it is seen that the force to generate the light is derived originally from the coal. It will be safe to give the indefatigable Professor fifty or even one hundred years to accomplish his object. It is undoubtedly the case, that the conversion of the coal into gas with the minimum of waste, the use of the gas to propel automatic gas engines for running dynamos (requiring, as they do, only 10½ per cent. of good illuminating gas and 89½ per cent. of air), and the use of improved conductors that will convey the electricity generated with less waste, is as much as the next century will be able to accomplish in perfecting the electric light.

In the meantime, many improvements have been made in gas burners intended to compete with and supersede the electric lights still remaining in use. Among them can be numbered the Bray cluster burners, the Siemens and the Siemens-Lungren regenerative burners. These burners furnish more powerful, steadier and cheaper lights than the electric light, require no engineers, firemen or costly machinery, and are steadily taking the place of the electric light where changes are made having economy in view. The whole effect, therefore, of electricity upon gas thus far has been : to hasten to perfection the high candle power water gas processes, to lower prices of gas to the consumers, to cause the invention and utilization of superior gas burners, gas engines and other appliances, to largely increase the consumption of gas, and to create a very strong demand for better apparatus for the manufacture of gas, especially as it is now seen that electricity can not supersede or compete with gas for fuel, power and heating purposes. It can therefore be safely concluded, that there is now no finer field of enterprise, and no direction in which capital can be more safely and profitably invested, than in pushing, to their fullest extent and largest development, the gas industries opened up by these new and superior processes and apparatus for the manufacture of high candle power gas for fuel, power and illuminating purposes.

PATENTS.

The following United States Patents, for improvements in the manufacture, burning and distribution of gas, have been granted to the author, viz. :

December	25, 1883	No. 290,925
December	25, 1883	" 290,926
December	25, 1883	" 290,927
December	25, 1883	" 290,930
April	6, 1886	" 339,471
April	6, 1886	" 339,472
May	11, 1886	" 341,506

Several applications for additional patents are now pending, which perfectly and fully cover various minor details of the system.

All of the designs contemplate a central fuel chamber, or chambers, connected with side steam superheating and gas fixing regenerative chambers, so constructed that the gases are discharged at the bases of the regenerative chambers, by which means the heats generated are retained within the apparatus and used to the best possible advantage. In this respect these designs are original, unique, and stand alone. In every other water gas apparatus the action of the regenerative chambers, with openings at the tops of the apparatus, tends to rapidly exhaust and waste the heat of the combustion chambers, thus making impossible the manufacture of gas at low cost.

The clear, distinct and broad claims allowed upon the patents have been thoroughly examined and compared with everything in the same line in American and Foreign Patents, by Benj. R. Catlin, Esq., the late able Chief Examiner in the department of gas and metallurgy in the United States Patent Office, and now of the National Law and Trust Co., Washington, D. C. His written report on the scope and validity of the patents on gas manufacture is summed up as follows, viz. : "The patents specify new, useful and efficient improvements, and the claims thereon are good and valid in law." It follows, that the National Law and Trust Co. are fully prepared to maintain and defend this opinion, the rights of the inventor and companies operating under these patents, in the United States Courts, should occasion arise therefor.

"BUSINESS."

The author desires to see gaseous fuel substituted for crude coal throughout the country, and the "smoke nuisance" a thing of the past, as soon as men and money can make the necessary changes in the present faulty processes of manufacture. To accomplish this, the cordial co-operation of all who are engaged in the useful and fascinating art of gas manufacture and of the construction of gas works is invited.

As the basis of profitable enterprises, verily, "there's millions in it," and the author is prepared to divide liberally with those who desire to push new enterprises in any direction, preferring to form no other monopolies than those that fairly earn the position by superior energy, activity and business ability, thus making room not only for all who are already familiar with, but also for others who wish to enter, this desirable field of operations.

To all, therefore, the author would say greeting; first secure the necessary licenses, next "be sure you are right, and then go ahead."

Chicago, 1887. H. C. REW.

CLAIMS.

In addition to many structure claims, covering the position of each chamber in the apparatus and the connecting pipes and flues, the "process claim" underlying these systems of gas manufacture, allowed to the author by the U. S. Patent Office, is as follows (see patents 339,471 and 341,506):

HEATING UP.

I claim—"the process of generating gas, which consists in blasting simultaneously two connected generating furnaces with air, admitting air also above the fires and burning the products of combustion, and carrying the resulting hot gases DOWNWARD through a superheating and a fixing chamber loosely filled with refractory material, thereby raising the fuel to incandescence and heating the brickwork;"

MAKING GAS.

"Then, passing air, gas, or steam, *or any mixture of the same*, UPWARD through the superheating chamber and through the two connecting furnaces, thereby decomposing the air, gas, or steam, and carbureting the resulting gases with the volatile hydrocarbons contained in the solid carbonaceous material, and with other liquid hydrocarbons, if desired;"

RE-HEATING, EXPANDING AND FIXING THE GASES.

"Then, forcing the resulting gases DOWNWARD through the heated brickwork in the fixing-chamber, thereby fixing and combining the gases into a homogeneous gas."

All infringements on the foregoing will be promptly and vigorously prosecuted.

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